high-resolution AC/DC voltmeter with LED display

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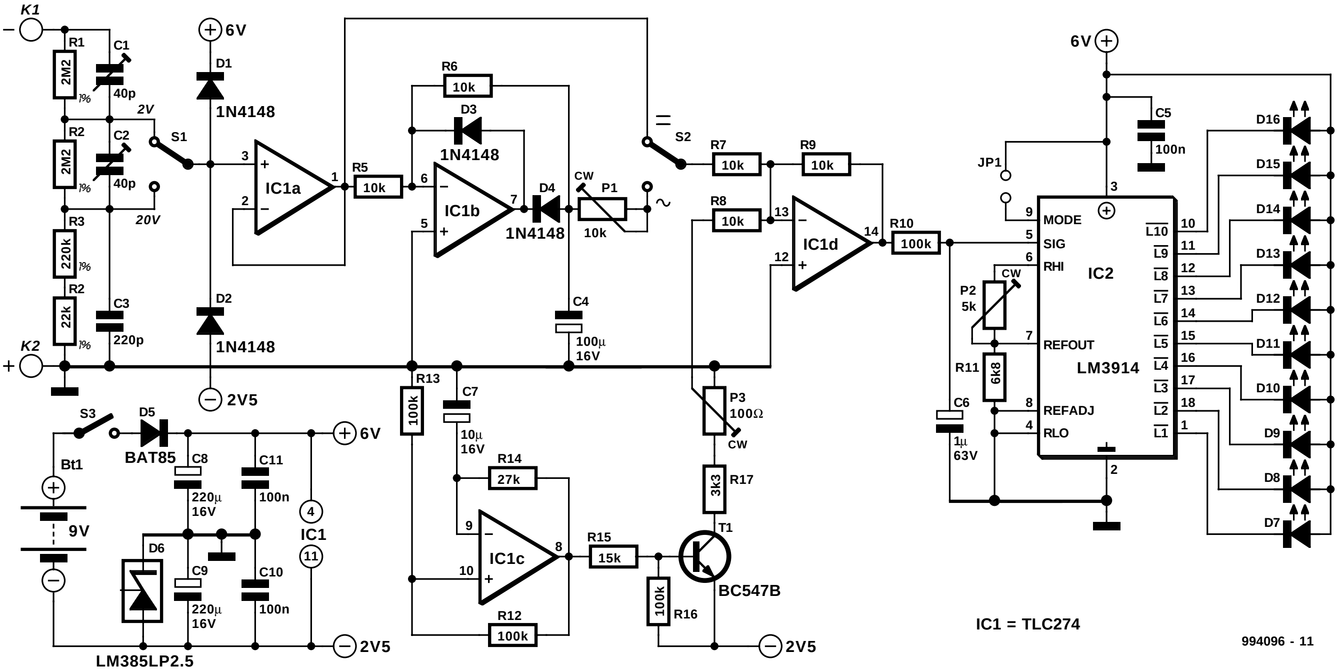

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Brief technical data

Measurement range	*100 mV–2 V, resolution 100 mV (AC/DC)*
	1–20 V, resolution 1 V (AC/DC)
Frequency range	*10 Hz – >10 kHz ±2 dB*
	about –2 dB at 100 kHz
Input impedance	*about 4.6 MΩ//20 pF*
Power supply	*9 V dry or rechargeable battery*
Current drain	*5 mA (stand-by)*
	≤ 6 mA (dot mode)
	≤ 20 mA (bar mode)

Voltmeters with LED display are very useful instruments for repair and maintenance work on electronic equipment. Unfortunately, their resolution is normally poor: of the order of ten per cent at the top end of the range. The instrument described in this article has a resolution at least twice as good and also measures audio frequency signals up to 10 kHz with small error.

Almost all such voltmeters use the well-known Type LM3914 LED driver which can control up to ten light-emitting diodes. This means that with a total measuring range of 0–2 V, the voltage difference between two adjacent LEDs is 200 mV. When a rectangular voltage at a level of half this voltage difference is added to the measurand, and the resulting signal exceeds 200 mV, the next higher LED flashes. This arrangement ensures a resolution of about five per cent at the top end of the range.

The diagram shows the circuit of the voltmeter arranged for measuring ranges of 2 V and 20 V. The divider at the input lowers the analogue signal to about 1/20 when the 20 V position of switch S_1 is selected. Capacitors C_1–C_3 provide frequency compensation up to about 10 kHz. Diodes D_1 and D_2 provide protection against overvoltages. Operational amplifier IC_{1a} functions as an impedance inverter.

Alternating voltages are measured with the aid of active rectifier IC_{1b}, which has excellent linearity/ During a positive half-wave of the signal the op amp operates as an inverting unity-gain amplifier ($R_5 = R_6$). Its output is negative, so that diode D_4 conducts, whereupon capacitor C_4 is charged to the peak level of the signal applied pin 6. During a negative half-wave, the output is positive, D_4 is reverse-biased, but the feedback is retained since diode D_3 then conducts. In the case of a direct-voltage input, the rectifier is bypassed by switch S_2.

Circuit IC_{1d} is a summing amplifier that combines the measurand and the 100 mV rectangular voltage. Since this stage inverts, whereas the LED driver requires a positive signal, the signals applied to the inputs of IC_{1d} must be negative with respect to earth. This is the reason for the somewhat unusual polarity of the rectifiers and the input terminals.

The rectangular signal is generated by IC_{1c} which, with component values as specified, oscillates at 1.6 Hz. This frequency may be altered within a wide range by changing the value of resistor R_{14} to individual requirements.

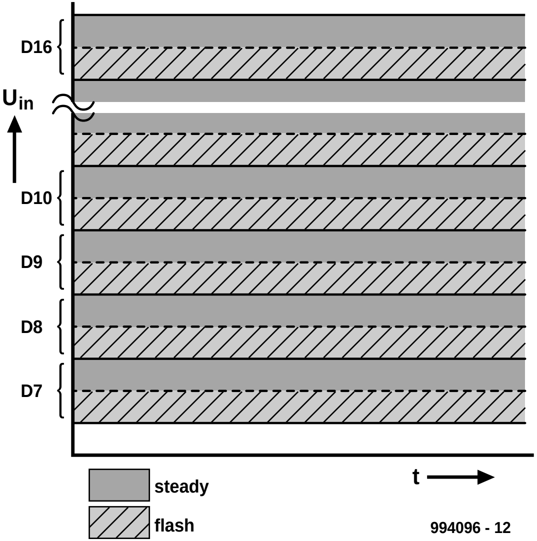
The output of the generator drives transistor switch T_1, which applies the –2.5 V signal periodically to potential divider R_{17}-P_3. The preset enables the exact level of the rectangular voltage to be set, whereupon this is applied via R_8 to pin 13 of IC_1 together with the measurand.

The LED driver, IC_2 is configured in a conventional manner. Its input pin 5 is preceded by filter R_{10}-C_6. The display mode is set with jumper JP_1: when this is left open, a bar display ensues; when it is closed, a dot display results.

The internal reference voltage of 1.25 V, which may be varied with preset P_2, is available at pin 7 (REF_{OUT}) and is used to set the brightness of the display. The current flowing from pin 7 via R_{11} and P_2 determines the LED current (about 1.7 mA). It is, of course, advantageous to use high-efficiency LEDs.

In the power supply section reference diode D_6 ensures that even with fluctuating currents and falling battery voltage the negative supply line remains a stable –2.5 V with respect to earth. This ensures that the voltage across P_3 is independent of the state of the battery.

Diode D_5 provides protection against polarity reversal and is a Schottky type to minimize voltage losses. The battery voltage may



drop to 5.5 V before the accuracy of the display begins to suffer.

So as to save energy, an on/off indicator is not provided, but where this is wanted, an LED with a 2.2 kΩ series resistor may be added between the output of IC_{1d} and the +6 V line.

Before the voltmeter can be used, it must, of course, be calibrated. This is begun by checking the potential divider at the input by connecting a digital voltmeter (DVM) at the output of IC_{1a} and applying a 2 V direct voltage (+ to earth) across the input terminals With S_1 in position 2 V, the DVM should indicate about 1 V. When S_1 is then set to position 20 V, the DVM should indicate about 0.1 V.

Next, set S_2 to position = and short-circuit P_3. Apply a voltage of exactly 2 V or 20 V (set S_1 accordingly) to the input terminals and adjust P_2 until D_{16} just lights. Remove the short-circuit from P_3 and apply a voltage of exactly 10 V (set S_1 to 20 V) across the input terminals. In the dot mode, D_{11} should light; in the bar mode, D_7–D_{11} should light. If D_{12} shows a tendency to flash, turn P_3 slightly towards earth until D_{12} is out.

Increase the input voltage to 11 V and adjust P_3 until D_{12} just begins to flash. When the input voltage is raised to 12 V, D_{12} should be fully on. In the dot mode, only one LED should light, but in practice it will be found that when the input is raised from 10 V to 11 V, D_{10} lights constantly and D_{11} begins to flash. When the input is raised slightly more, both diodes light until D_{10} goes out. A clearer indication is obtained in the bar mode, but this adds to the current drain from the battery.

The AC range is calibrated by setting trimmer C_1 to its centre position (use an insulated small screwdriver) and applying a 100 Hz sinusoidal signal to junction R_1-R_2 (earth to K_2). Set S_1 to 20 V. Connect a DVM (10 V d.c. range) across C_4, set S_2 to <> and adjust the generator output until the DVM reads ≤ 1.4 V. Keep the generator output constant, change the frequency to 10 kHz, and adjust trimmer C_2 (insulated screwdriver) until the DVM reading is the same as with 100 Hz.

Next, set S_1 to 2 V and repeat the procedure just described at the same frequencies and adjust C_1 as before. Since the settings of the trimmers influence one another, the calibration of the AC ranges must repeated a couple of times, setting C_1 with S_1 in the 2 V position and C_2 with S_1 in the 20 V position. A properly calibrated divider is virtually linear up to about 10 kHz.

Finally, to set the sensitivity of the instrument, apply a 100 Hz sinusoidal signal at an accurately known level to the input terminals and adjust P_1 until the LED display shows the r.m.s. value of the input signal. [994096]